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**54** An arrangement for compensating errors in a quadrature modulator.

**57** An arrangement for compensating errors occurrent in a quadrature modulator. The modulator includes means (1) for generating quadrature signals ( $\cos a(t)$ ,  $\sin a(t)$ ) in the baseband, each of which signals is delivered to a respective branch in the modulator; means (2) for generating two high frequency signals ( $\cos wt$ ,  $\sin wt$ ) with a mutual phase difference of 90 degrees; mixers (3, 4) for mixing the quadrature signals ( $\cos a(t)$ ,  $\sin a(t)$ ) with the high frequency signals ( $\cos wt$ ,  $\sin wt$ ) and an adder (5) for producing the sum of the output signals of the mixers (3, 4). Amplitude errors and phase errors are compensated with the aid of a separate compensating network (11, 12, 14, 16, 17, 19, 21) which is incorporated in the low frequency part of the modulator and which includes adjustable signal generating means (14, 16, 19). Local oscillator leakage is compensated with the aid of a second compensating network (13, 15, 18, 20) which is also incorporated in the low frequency part of the modulator and which also includes adjustable signal generating means (15, 18). The signals ( $k_4$ ,  $k_5$ ) from the latter means (15, 18) are subtracted from the signals occurring in the two branches of the modulator.

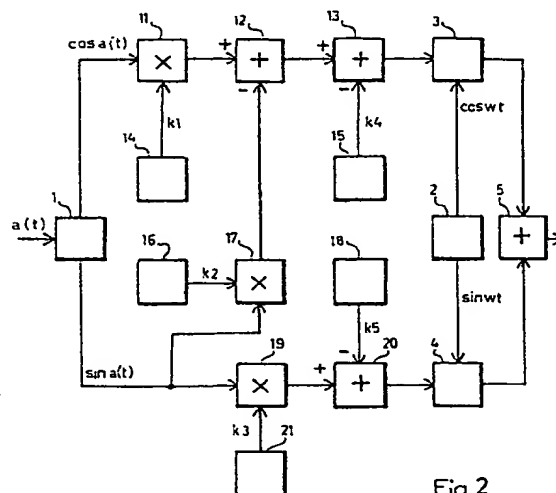


Fig.2

## Description

## AN ARRANGEMENT FOR COMPENSATING ERRORS IN A QUADRATURE MODULATOR

## TECHNICAL FIELD

The present invention relates to an arrangement for error compensation in a quadrature modulator of the kind which includes means for generating in the baseband two quadrature signals, each of which is applied to its respective branch in the modulator, means for generating two high frequency signals with a mutual phase difference of 90 degrees, a mixer for mixing the quadrature signals with the high frequency signals, and an adder for producing the sum of the mixer output signals. The errors concerned are errors in amplitude, phase errors, and error caused by local oscillator leakages.

## BACKGROUND ART

In the case of a quadrature modulator of the aforesaid kind errors in amplitude and errors in phase can occur, for instance, in the high-frequency signal generating means, in the mixers and in the adder. Phase errors may also occur as a result of different wave lengths on, for instance, pattern cards in the modulator. In order to achieve the result desired, the amplitude error and phase error in the modulator should not exceed about 1/2 dB and about 3 degrees respectively. It is difficult, however, to achieve such low values for frequencies which are higher than some 100 MHz. For example, the wave length at 1000 MHz is about 3 dm, which means that one (1) degree will correspond to a distance in the order of one (1) mm.

Local oscillator leakages occur as result of the leakage of signals through the mixers from the high frequency signal generating means. Leakage signals can result in so-called widening of the spectrum range, particularly when using non-linear transmission terminal stages, which in turn can result in disturbances in neighbouring traffic channels. It is known to attempt to counteract the occurrence of amplitude and phase errors and local oscillator leakages, by using components which have relatively good properties, although costs then become comparatively high.

## DISCLOSURE OF INVENTION

The object of the present invention is to provide an arrangement which will avoid problems arising from amplitude and phase errors and local oscillator leakages in a quadrature modulator of the aforesaid kind. This object is achieved by incorporating in the low frequency part of the modulator a separate compensating network which includes adjustable signal generating means.

The characteristic features of the invention are set forth in the following claims.

## BRIEF DESCRIPTION OF DRAWING

The invention will now be described in more detail with reference to the accompanying drawing, in which Figure 1 illustrates a known quadrature modulator and Figure 2 illustrates a quadrature

modulator which is equipped with an arrangement constructed in accordance with the invention.

## BEST MODE FOR CARRYING OUT THE INVENTION

Figure 1 illustrates a known quadrature modulator. The reference sign 1 identifies a means for generating two quadrature signals in the baseband, these signals being designated  $\cos a(t)$  and  $\sin a(t)$  respectively. The reference sign 2 identifies a means for generating two high frequency signals,  $\cos wt$  and  $\sin wt$  respectively, which are of the same frequency but have a mutual phase difference of 90 degrees. Each of these signals is delivered to a respective mixer 3, 4, in which said signals are mixed with the quadrature signals in the baseband. The mixer output signals are delivered to an adder 5, the output of which produces signals  $\cos wt \times \cos a(t) + \sin wt \times \sin a(t)$ . This signal can also be designated  $\cos (wt - a(t))$ .

However, in practice the signal from the adder will be influenced by amplitude error, phase error and oscillator leakage, and can therefore instead be designated  $\cos wt \times \cos a(t) + A \times \sin (wt + V) \times \sin a(t) + L \times \cos (wt + U)$ . In this expression, A represents the amplitude error, V the phase error and  $L \times \cos (wt + U)$  the oscillator leakage, the error conceivably only occurring in one branch, the lower branch, of the modulator.

Figure 2 illustrates a quadrature modulator which includes an arrangement constructed in accordance with the invention. Means which have correspondence in Figure 1 have been identified with the reference signs previously used therefor. The reference signs 14, 16 and 21 identify adjustable signal generating means which are operative in generating signals designated  $k_1$ ,  $k_2$  and  $k_3$ . The quadrature signal  $\cos a(t)$  is multiplied by the signal  $k_1$  in a multiplier 11, and the quadrature signal  $\sin a(t)$  is multiplied by the signal  $k_2$  in a multiplier 17. The output signal from the multiplier 17 is subtracted from the output signal from the multiplier 11 in a subtractor 12. A signal  $k_4$  generated in an adjustable signal generating means 15 is subtracted in a subtractor 13 from the output signal from the subtractor 12. The signal formed is thus  $k_1 \times \cos a(t) - k_2 \times \sin a(t) - k_4$ .

The quadrature signal  $\sin a(t)$  is also delivered to a multiplier 19 in which it is multiplied by a signal  $k_3$  from an adjustable signal generating means 21. A signal  $k_5$  generated in an adjustable signal generating means 18 is subtracted from the output signal of the multiplier 19 in a subtraction circuit 20. The signal  $k_3 \times \sin a(t) - k_5$  is formed in the subtraction circuit 20.

The signal  $(k_1 \times \cos a(t) - k_2 \times \sin a(t) - k_4) \times \cos wt + (k_3 \times \sin a(t) - k_5) \times A \times \sin (wt + V) + L \times \cos (wt + U)$  is obtained on the output of the adder 5. Similar to the case aforesaid, A is the amplitude error, V is the phase error and  $L \times \cos (wt + U)$  is the oscillator leakage. When extended, this expression becomes  $k_1 \times \cos a(t) \times \cos wt - k_2 \times \sin a(t) \times \cos$

$w t - k_4 \times \cos w t + A \times k_3 \times \sin a(t) \times \sin w t \times \cos V +$   
 $A \times k_3 \times \sin a(t) \times \cos w t \times \sin V - A \times k_5 \times \sin w t \times \cos$   
 $V - A \times k_5 \times \cos w t \times \sin V + L \times \cos w t \times \cos U - L \times$   
 $\sin w t \times \sin U.$

Two equations which include  $k_4$ ,  $k_5$  and  $L$  can be compiled from the above expression.

$$- k_4 \times \cos w t - A \times k_5 \times \cos w t \times \sin V + L \times \cos w t \times \cos U = 0 \quad (1)$$

$$- A \times k_5 \times \sin w t \times \cos V - L \times \sin w t \times \sin U = 0 \quad (2)$$

Values for  $k_4$  and  $k_5$  can be determined from these equations and used to compensate for oscillator leakage.

From equation (2) there is obtained

$$k_5 = - L \times \sin U / (A \times \cos V).$$

If this expression is inserted in equation (1),  $k_4 = L \times (\cos U + \sin U \times \sin V / \cos V)$  will be obtained.

If the above expressions containing  $k_4$ ,  $k_5$  and  $L$  are eliminated from the expression which represents the signal on the output of the adder 5, the expression  $k_1 \times \cos a(t) \times \cos w t - k_2 \times \sin a(t) \times \cos w t + A \times k_3 \times \sin a(t) \times \sin w t \times \cos V + A \times k_3 \times \sin a(t) \times \cos w t \times \sin V$  will remain. If  $k_1$  is made equal to  $\cos V$ ,  $k_2$  is made equal to  $V$  and  $k_3$  is made equal to  $1/A$ , the second and fourth terms cancel out each other. There then remains  $\cos V \times \cos a(t) \times \cos w t + \sin a(t) \times \sin w t \times \cos V = \cos V \times (\cos w t \times \cos a(t) + \sin w t \times \sin a(t)) = \cos V \times \cos(wt - a(t))$ . With the exception of  $\cos V$  this expression is equal to the ideal expression derived in connection with the Figure 1 embodiment without taking into account amplitude error, phase error and local oscillator leakages. Since  $V$  represents the phase error and this error can be assumed to have a small value, the value of  $\cos V$  in practice will be slightly less than one (1).

When using an arrangement constructed in accordance with the invention, with suitably adjusted values of the signals  $k_1 - k_5$ , the residual error in the output signal of the modulator will consist solely of a constant amplitude factor which is slight smaller than one. This factor has no significance in practice, however.

Thus, the inventive arrangement comprises a compensatory network which includes adjustable signal generating means and which is incorporated in the low frequency part of the modulator. This compensating network, however, can be said to consist of two separate networks, of which one compensates for amplitude and phase errors and the other compensates for local oscillator leakages. The networks are thus capable of functioning independently of one another.

According to one practical embodiment, the compensating network may comprise operational amplifiers and trimmable resistors. Adjustment of the signals  $k_1 - k_3$  can be effected in the following manner. When  $a(t)$  is chosen as  $(w_m \times t)$ , the ideal output signal of the modulator will be  $\cos(w \times t - w_m \times t)$ , i.e. it will include solely the frequency  $w - w_m$ . In practice, however, a further frequency component is formed as a result of errors in phase and amplitude. This further frequency component can be caused to disappear with the aid of a spectrum analyser and by changing the signals  $k_1 - k_3$  iteratively. Correspond-

ingly, an undesired frequency component caused by local oscillator leakage can be caused to disappear, by changing iteratively the signals  $k_4$  and  $k_5$ .

## Claims

1. An arrangement for compensating errors occurrent in a quadrature modulator which includes means (1) for generating two quadrature signals ( $\cos a(t)$ ,  $\sin a(t)$ ) in the base-band, each of said signals being delivered to its respective branch in the modulator; means (2) for generating two high frequency signals ( $\cos w t$ ,  $\sin w t$ ) with a mutual phase difference of 90 degrees; mixers (3, 4) for mixing the quadrature signals ( $\cos a(t)$ ,  $\sin a(t)$ ) with the high frequency signals ( $\cos w t$ ,  $\sin w t$ ) and an adder (5) for producing the sum of the output signals of said mixers (3,4), characterized in that the arrangement further includes adjustable signal generating means (14, 16, 21) for generating a first ( $k_1$ ), a second ( $k_2$ ) and a third ( $k_3$ ) signal; a means (11) incorporated in one branch of the modulator for forming a fourth signal which constitutes the product of the one quadrature signal ( $\cos a(t)$ ) and said first signal ( $k_1$ ); a means (17) for forming a fifth signal which constitutes the product of the second quadrature signal ( $\sin a(t)$ ) and said second signal ( $k_2$ ); a means (12) incorporated in said one branch for forming a sixth signal which constitutes the difference between said fourth signal and said fifth signal; and a means (19) incorporated in the other branch of the modulator for forming a seventh signal which constitutes the product of the second quadrature signal ( $\sin a(t)$ ) and said third signal ( $k_3$ ), whereby amplitude error and phase error are compensated by suitably adjusted values of said first to third signals ( $k_1 - k_3$ ).

2. An arrangement according to claim 1, characterized in that the arrangement further includes adjustable signal generating means (15, 10) for generating an eighth ( $k_4$ ) and a ninth ( $k_5$ ) signal; a means (13) incorporated in one branch of the modulator for forming a signal which constitutes the difference between said sixth and eighth signals; and a means (20) incorporated in the other branch of the modulator for forming a signal which constitutes the difference between said seventh and ninth signal, whereby local oscillator leakage is also compensated with the aid of suitably adjusted values of said eighth ( $k_4$ ) and ninth ( $k_5$ ) signals.

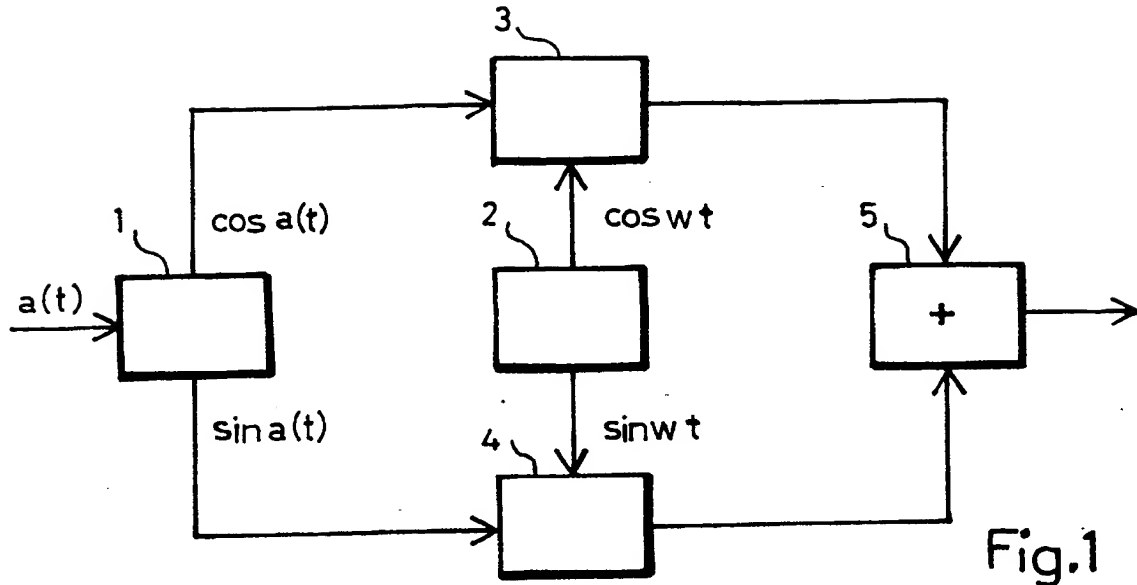


Fig.1

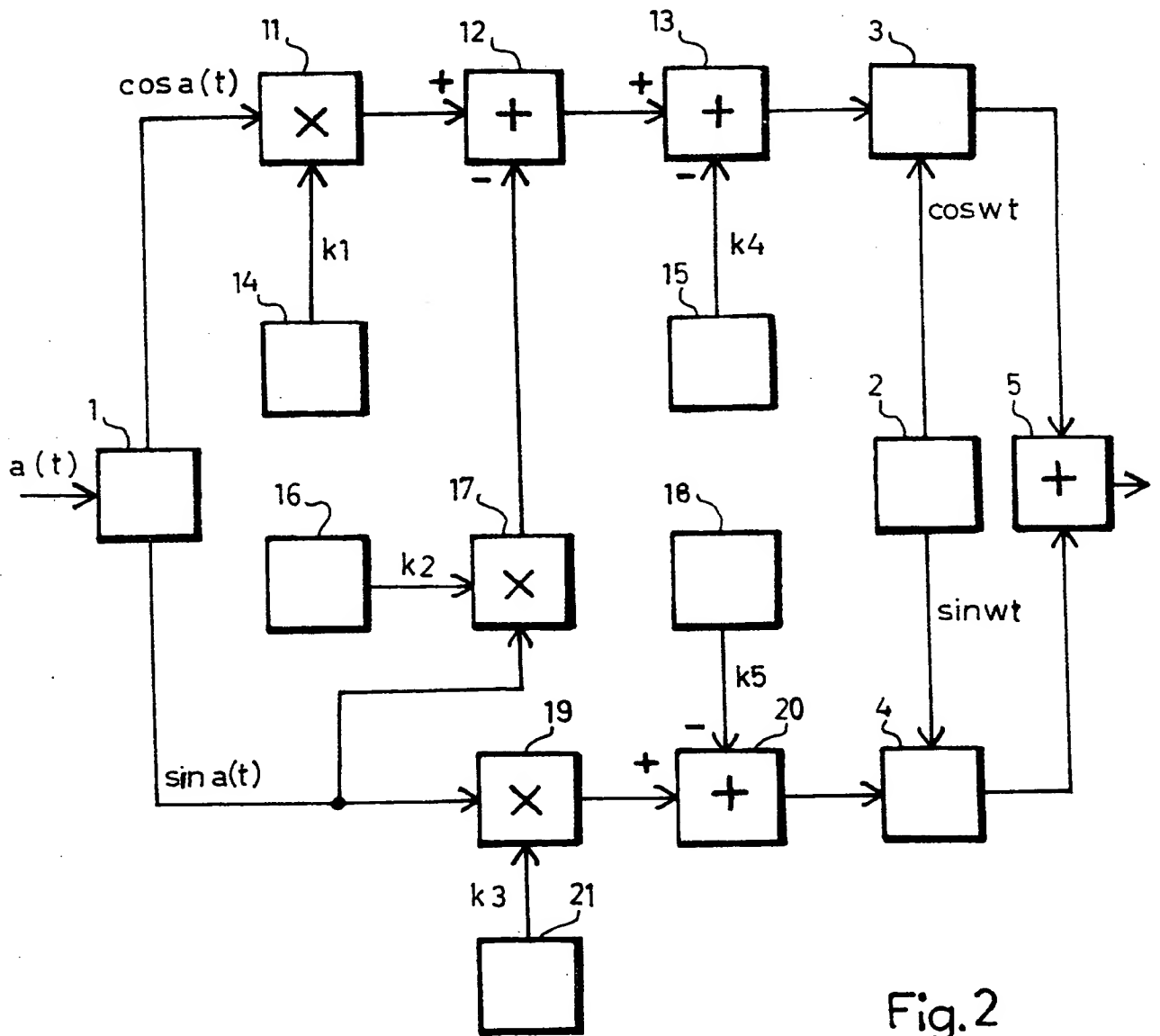


Fig.2



DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. <sup>4</sup> )
A	US-A- 4 700 151 (NAGATA)	1-2	H 03 C 3/00
A	US-A- 4 565 980 (ASHIDA)	1-2	
			TECHNICAL FIELDS SEARCHED (Int. Cl. <sup>4</sup> )
			H 03 C H 04 L
The present search report has been drawn up for all claims			
Place of search STOCKHOLM		Date of completion of the search 04-02-1989	Examiner JONSSON B.
<b>CATEGORY OF CITED DOCUMENTS</b>			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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